ANALYSIS OF THE SHORTWAVE CLOUD FORCING AND SURFACE SHORTWAVE FLUX IN THE METEOROLOGICAL AND OCEANOGRAPHIC (METOC) MODELING AND PREDICTION SYSTEMS

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LONG TERM GOALS

The United States Navy is the Department of Defense's main source for standard meteorological and oceanographic (METOC) predictions. At the heart of these predictions are the short-to-medium range weather forecasts produced by the Navy Operational Global Atmospheric Prediction System (NOGAPS; Hogan and Rosmond, 1991). Surface flux fields from NOGAPS forecasts are used as input to the oceanographic prediction systems. These systems include: 1) the Thermodynamic Ocean Prediction System, 2) the Polar Ice Prediction System, and 3) the Third Generation Wave Model. Given the prominent role surface fluxes play in these systems, it is clear that their proper simulation by NOGAPS is vital. Presently, there are significant shortcomings in the NOGAPS simulation of the net surface shortwave flux (long-term mean biases greater than 50-80 Wm^{-2} in many tropical/subtropical areas), as well as other surface heat flux components (similar size biases in the latent and net surface heat fluxes). The long term goal of this research is to determine the underlying causes for these shortcomings and help implement modifications for improvement in order to: 1) enhance this model's physical representation of the atmosphere and extend the skill of its medium range weather predictions, and 2) improve the skill of the oceanographic and coupled prediction systems via the improved simulation and prediction of the surface energy budget.

OBJECTIVES

The objectives of this research are to analyze and improve/verify the model representation of the shortwave flux and associated related cloud-radiative processes. The methodology to carry out these objectives includes the following: 1) comparison and analysis of observations and model output of top of the atmosphere (TOA) radiative fluxes, including clear and cloudy skies; 2) comparison and analysis of observations and model output of cloud characteristics, including frequency, type and optical properties; and 3) comparison and analysis of observa-tions and model output of surface rainfall, latent and shortwave fluxes, with the latter includ-ing clear and cloudy skies, and up- and down-welling components. These comparisons will help identify the parameterizations which underlie the large biases evident in the modeled surface shortwave. In conjunction with the NOGAPS modeling team, these parameterizations can then be examined in detail in order to design and implement improvements.

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APPROACH

Assemble satellite-based and ground-based verification data sets and repackage them into data formats that will facilitate comparison to NOGAPS simulation output. These data sets include the ERBE products, ISCCP cloud products, MSU precipitation, SSM/I precipitable water, ship-based surface heat flux climatologies, AVHRR aerosol retrievals, as well as satellite surface shortwave data sets. Assemble the necessary output parameters from the most recent NOGAPS AMIP-like simulation (via Timothy Hogan, NRL, Monterery) and repackage into data formats that will facilitate the analysis. Begin performing the TOA analysis/comparison on the climatology between NOGAPS and the available satellite observations. In parallel, begin the surface comparisons to highlight regions where the apparent model and observation discrepancies are consistent between the TOA and surface. Focus the TOA and surface analysis on those areas which show greatest discrepancies with observed data, and in particular that exhibit consistent discrepancies (e.g., too little shortwave at the surface in the same regions where the cloud forcing at the TOA is too large). In these regions compare the model and observed cloud information. In cases where the cloud information is fairly agreeable, this would like suggest a change to the parameterization of the cloud optical properties rather than a change to the model physics that produces the cloud. In cases where the cloud amounts do not agree, this would suggest a deficiency in the cloud parameterization schemes. From these model comparisons, and in collaboration with the NOGAPS modeling team, determine the underlying causes for these parameterization deficiencies, suggest improvements in the model formulations, and re-analyze the new simulations based on the improved physical parameterizations.

WORK COMPLETED

Nearly all the initial Year-1 objectives have been completed during the first six months of the award period. Nearly all surface and TOA data sets required for the project have been acquired and re-formatted for the purpose of the analysis. Dr. Hogan (NRL) has run a 15-year simulation of the NOGAPS model for the analysis and provided the output to the PI. Long-term mean model-data comparisons have been carried out at both the surface and the TOA to identify the underlying causes of the shortwave biases in NOGAPS model. The results of these comparisons have been "published" on the web, presented to the Global Modeling Division at NRL and are described briefly below.

RESULTS

The figure below shows a schematic representation of the model atmosphere that attempts to tie together most/all of the significant model biases found in the tropical/subtropical areas. The upper diagram shows a representation of the "observed" atmosphere. Air moves equatorward to warmer

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and warmer sea surface temperature (SST). As it does, it moistens through local latent heat flux, releases some via instability and convective rainfall, but transports a significant amount to the warmest, most convective regions of the tropics. The ensuing deep convective rainfall in these areas produces a strong upper-level circulation that in turns help suppress the weaker convection in the subtropical areas. The lower diagram shows a representation of the NOGAPS atmosphere. In this case, convection occurs too frequently/readily in the poleward/cool tropical areas. This causes a rapid recycling of water vapor locally which increases the evaporation, cloudiness, and rainfall in these areas and decreases the surface shortwave and all-sky OLR. Because the convective instability is released too early, not enough water vapor is transported to the warmest and (typically) most deep-convective areas leaving the atmosphere in this region too dry. The early release of the

instability also means that there are too few clouds (and/or clouds that are too low), too little rain, and too much OLR and surface shortwave in these regions. Overall, the lack of deep convection in these very warm areas reduces the strength of the circulation, which in turn does not produce the needed subsidence in the subtropical areas to help suppress the local instability. At present, these problems point to a shortcoming in the convective parameterization and/or maybe the boundary layer formulation.

IMPACT

Due to the short duration of the project to date (4/1/97-present), the hypotheses described above has not been transitioned into a practical impact as yet. The intention is to use the results above to improve the simulation quality of the shortwave and evaporative fluxes produced by NOGAPS in order to: 1) enhance this model's physical representation of the atmosphere and extend the skill of its medium range weather predictions, and 2) improve the skill of the oceanographic predictions via the improved simulation and prediction of the surface energy budget.

TRANSITIONS

The transition of results of this work will occur via the collaboration between the PI and the Global Atmospheric Modeling Division at NRL. The intention is to take what is learned (i.e., Figure 1) and identify specific parameterizations that can improved, implement and test these improvements in conjunction with the NOGAPS modeling team, and then transition these improvements into the operational forecast system.

RELATED PROJECTS

The PI is also investigating the simulation quality of the Madden-Julian Oscillation (MJO) in the NOGAPS model. This intraseasonal phenomena has significant influence on tropical rainfall variability and the onset and breaks of the Asian-Australian monsoons, as well as minor influence on long-range mid-latitude weather forecasts. Dr. Hogan (NRL) has supplied daily output for a number of variables from the same simulation described above in order to assess the simulation of this process. This work is being done in conjunction with the PI's study of the MJO in the NASA GLA and NCAR CCM2/3 atmospheric GCMs which is supported by NSF.

REFERENCES

Hogan, T. F., and T. E. Rosmond, 1991: The Description of the Navy Operational Global Atmospheric Prediction System's Spectral Forecast Model. *Mon. Wea. Rev.,* **119**, 1786-1815.

For more complete details, see: *http://terra.msrc.sunysb.edu/onr/nogaps.html*